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ABSTRACT

Reported is a study to investigate the effects of a free-choice program on children's ability to interpret experiments, design simple investigations, and recognize variables that could affect the outcome of observed events. (Author/SA)

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ADVANCING EDUCATION THROUGH SCIENCE-ORIENTED PROGRAMS,[1]

REPORT PSc-15

Learning in the Choice Environment[2]

by

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[2]Presented at the NARST Convention, April 23, 1973, San Francisco, California.

In our research we have been investigating the effects of a free choice program on children's ability to interpret experiments, design simple investigations, and recognize variables that might affect the outcome of observed events. We decided to aim our program towards 9 - 13 year olds, both because Inhelder and Piaget's (1957) research indicated that this group would be likely to profit from instruction in interpreting experiments and controlling variables and because little work has been done with that age group.

Rather than attempting to diagnose the experiences appropriate for each child, we are currently exploring the feasibility of providing what we call a free choice situation where participants can choose which of a wide variety of activities they wish to pursue and can determine to some extent how they interact with the activity.

Relevant to Piaget's emphasis in the importance of interaction with objects and organisms for the development of logical reasoning, we have assumed that students in a free choice environment will choose activities which will help them learn. Clearly, however, the characteristics of the program will determine what and how much the students learn.

If most 10 year olds are given dolls and trucks or geiger counters and centrifuges, they will probably not choose experiences which will foster scientific reasoning. The materials must, in some way, relate to the children's available knowledge and stimulate them to uncover new relationships. In this paper, we will discuss additional characteristics of a free choice program which we have found influences how students profit from the experience and how the program functions. Thus, we will focus on activity format,

program leadership, and student record keeping. We will also discuss evaluation strategies which we have found useful in understanding better the effects of the program on the individual.

Activity Format

The question we faced when choosing an activity format was: what method of presenting activities to students promotes independent investigation?

Apparatus only. An early study involved providing a wide range of apparatus along with demonstrations of suggested ways to use the various materials (Linn, Chen, Thier, in press). Whole classes of children in their regular classrooms participated.

Choice of apparatus. Activities in an individualized program must reflect the interests of the children. Therefore, we asked a group of 11 year olds to list the science activities they would most like to do. From these lists, which were quite general, like "work with chemicals," "make things fly," and "investigate oil spills," we developed apparatus for about 30 different activities including testing the acidity of various substances, flying rubber band-powered airplanes, and saving goldfish from oil spills.

Presentation of activities. Students attended a project preview where they circulated around the room and all the apparatus for the program was demonstrated by project staff. Following this preview, students selected their apparatus and did experiments. They were asked to make reports on their results before changing to new apparatus.

Challenge and follow up format. We found (Linn, Chen, and Thier, 1975) that students were having difficulty divising experiments for unfamiliar variables. Thus we tried changing our challenges into activities and provided challenges without directions to encourage students to follow up on new ideas (see Figure 2).

During the activity phase specific instructions in how to carry out an experiment are given. After the student is familiar with the apparatus, he carries out one or several challenges for which no directions are given. This format appears to encourage independent exploration more than the others we have tried. Consistent with other work (Linn, Levine, 1976), it appears that students are more likely to carry out controlled experiments for familiar variables than for unfamiliar variables.

Program Leadership

In a free choice activity program, a leader must at least be responsible for organizational procedures such as apparatus distribution, technical problems and supervisory clean up. In this case the leader could encourage the development of scientific reasoning skills by stimulating students to explore the role of particular variables and to design controlled experiments. We will discuss organizational procedures and instructional responsibilities of leaders separately.

Organizational procedures. In our first program trial the leader was responsible for distributing apparatus from a central storage area as well as keeping track of which student was doing what experiment. This was

possible only because we had several leaders present for each session. In our second trial we placed equipment for each activity in a different box and had the leader distribute the boxes. We found that allowing students to continue with apparatus from one session to the next caused severe storage problems in most classrooms and meant that we needed great quantities of equipment if more than one class was doing the program.

As a result of these trials, we developed a format where all apparatus unique to an activity and the activity directions are placed in ice cream cartons. The cartons are labeled and stored on open shelves. Apparatus common to several activities is placed adjacent to the shelves in a master box. Students select an activity, take the ice cream carton, get any additional materials from the master box, carry out the activity, clean up and return the apparatus to shelves and master box during one visit to the program (usually one hour). Under these conditions the leader is free to concentrate on other aspects of the program. We have experimented with having students record which activity they were doing but have found this is most effectively done by the leader. Thus, the leader circulates around the room noting what activity each student is doing and answering questions. One leader can manage this program for about 20 students at once.

Instruction in Experimentation

While experience with apparatus is necessary for the development of scientific reasoning, instruction appropriate to the abilities of the students might also be useful. We first tried providing an introduction to variables and experimentation where students all used the same apparatus

in directed experiments similar to the Science Curriculum Improvement Study (SCIS) format. After the introduction, the students participated in the free choice program. This first trial convinced us that the free choice program would be more appropriate as an enrichment program outside the regular classroom and led perhaps by a paraprofessional or parent volunteer. We tried to provide an introduction compatible with the enrichment concept. One approach was to include ideas about variables and experimentation; we found this was an inappropriate way to influence children's understanding of variables and experimentation.

It seemed clear that instruction in experimentation and variables would require an active leader. The program at this point was very successful in involving students in experimentation. We have explored both the role of the leader in the free choice environment and the role of a teacher supplementing the free choice program.

Role of leader in free choice program. Either parent volunteers or paraprofessionals are the usual leaders in enrichment programs such as this one. The goal of making a program "teacher-free" is sometimes heard from proponents of Computer Assisted Instruction. Piagetian oriented educators often take the other side: asserting that drastic changes in the teacher are needed to create a new program. Furth and Wacks (1974) spent three weeks in the summer, one week in the fall, and four days a month throughout the year training one teacher to teach children how to think. While this procedure is effective, it is both time consuming and expensive.

Our first plan, then, was to devise a rather teacher-free program--one that would work no matter who the leader was. Since we also wanted the full potential of the leader to be realized, however, we had to create a means for this. Thus, we first devised procedures for students to check activities in and out themselves as noted above. The leader performed only truly essential functions like ordering new supplies and reminding students to return to their classes (a frequent and flattering problem). The leader was now free to talk to the students. Subsequently, we tried having the leader interview students when they finished their activities. The interview was designed to find out what the child was thinking, not to evaluate. We encouraged the leader to ask any additional questions that would help clarify what the child had done and what it meant. We were encouraging the leader, from experiences as an interviewer, to ask thought-provoking questions rather than providing information.

Instruction in experimentation. Our instructional program in experimentation was designed to be led by a trained teacher meeting with a group of students six to eight times for fifteen minutes. Developed by Beni Chen, this program is eclectic, based on SCIS, practical experience, and Smedslund's idea of cognitive conflict. The concepts of variable and fair experiment are introduced for a familiar situation like a basketball game in the first session. Each additional session focuses on an activity from the free choice program. The students name the variables for this activity and criticize experiments proposed by the leader. Each "unfair" experiment is compared to the basketball game. Students are asked whether it would be "fair" to have a lower hoop for one team and then whether it would be fair to release one sphere from a lower position if you wanted to find out which would roll

furthest. Unfair experiments are set up which yield logically unacceptable results, students discuss why this happens. Students are asked to set up experiments which are discussed by the group.

Results so far indicate that this form of instruction is quite effective. The relative importance of the free choice program and the instruction is currently being investigated. It appears that free choice experience with apparatus is much more effective when combined with instruction (see Linn, Chen and Thier, 1975; Chen and Wollman, in preparation).

Student Record Keeping

A problem which we found very difficult to resolve is that of student record keeping. Our observation is that students profit from reflecting on what they find out with one set of equipment before going on to another topic. Methods which help students accomplish this are generally perceived negatively by the participants because they involve writing and thinking over what has been done instead of doing something new.

It seems reasonable to request reporting of one sort or another when the student changes activities since this is a natural break in his investigation. In our first trial we required students to draw or write reports of what they found out using their equipment. Some students complained or did not want to change equipment because they did not want to make reports.

In our second study both interviews and reports were used (Figure 3). Students were encouraged to fill out the report form before the interview,

but these questions were asked during the interview if they had not been answered beforehand. Students enjoyed discussing their experiments with the leader, especially if something unexpected had happened. This system was, therefore, more appealing to the students than just writing reports, but did not always lead to reflection on what had been done and took a lot of leader time.

In the later trials we have required students to answer questions printed on the activity instructions (see Figure 2) but not required reports. Students are much happier with this arrangement and still reflect before starting on a new activity. For challenges we asked the students to report orally to the leader and the whole group if there was interest. Reports to the group have often generated valuable discussions of experimentation.

Reporting does appear to be a learning experience. Written reports, however, appear to provide practice in writing rather than to encourage experimentation. Oral reports or interviews seem most effective. Short answer questions focusing on the variables in each experiment are useful and usually acceptable to students.

Evaluation

We have been concerned with whether our program is accomplishing its stated goals (improved ability to recognize and control variables) and with what other effects the program might have.

Measuring scientific reasoning. To measure ability to control variables we first developed some group measures. These were apparatus related questions presented on film. Students wrote their answers to each question. The procedure was to bring in the apparatus for the test such as a ramp and rolling sphere, identify each element, demonstrate the apparatus, show a short film segment which gave a more detailed demonstration, read the first question, show a film illustration of the question, allow all students to answer the question, and read, watch, and answer the remaining questions. Some typical questions are shown in Figure 4. Questions covered recognition of variables, controlling variables, recognizing uncontrolled variables, and interpreting experiments.

We found that paper and pencil evaluation measures presented the same problems we encountered when we required students to write reports. Many students dislike writing. The program does not teach or even depend on writing. In keeping with our philosophy of evaluating in the same mode we use for instruction, we decided to use interviews instead of group tests.

We have used interviews based on Piagetian tasks like Bending Rods or Spinning Wheels (Inhleder & Piaget, 1958) and interviews we have devised ourselves (Linn & Levine, 1976). All have included active experimentation by the subject, the subject's reasons for each experiment and counter suggestions posed by the interviewer. These measures, since they are similar in format to activities used in the program, have been very useful.

Measuring how the program works. Program outcomes have been assessed by summarizing student reports and leader interviews done during the free

choice program (Linn, Chen, & Thier, 1975). Another approach has been to report case studies (Linn, Chen, & Thier, in press). We have also looked at student choices, duration of activity use, and activity popularity.

All of these approaches have helped to effectively characterize what happens during the free choice program. Outcomes of this evaluation approach have indicated that subjects in the program behave in a manner compatible with Piaget's stage of concrete operations.

Conclusions

In the course of our research on the behavior of individuals in free choice program we have been guided by Piagetian theory. Primarily we found that translating theory into practice involves much trial and error. Many questions cannot be answered by theory alone. On the other hand, we have found the concept of concrete operations to be a succinct way to relate and explain many diverse observations in our free choice program.

We have found that program development provokes questions about the development of logical reasoning and that investigation of these questions facilitates development of teaching procedures. For example, observations in a free choice program have suggested that students focus on the results of their experiments rather than the procedure. That is, students are more interested in making the slider go far than in finding out if one position is better than another. Following up this observation, in an interview study (Linn and Levine, 1976), we found that 12 year olds accept the results

of uncontrolled experiments even when they appear quite unreasonable. For instance, subjects accepted that a smaller marble could hit a target farther than a larger marble when they watched an uncontrolled experiment. We are now investigating the implications of this finding for the teaching program.

Many questions are still unanswered. We have a better understanding of how the leader can foster scientific reasoning, how to design activity directions to encourage individual exploration, how to structure student participation to encourage reflection and how to evaluate student progress. We will be continuing to try out variations of free choice programs to determine how best to provide an enjoyable program which is likely to improve the students scientific reasoning ability.

Throughout our early work the development and trial of activities has provided the laboratory in which to carry out our research on reasoning. The evolvement of activities of high interest to participants has provided us with a reproducible set of conditions in which to study children's reasoning. All variables cannot be controlled because the program is only one aspect of the child's school and life experience.

We now know some of the parameters of a free choice experience. By careful on-site evaluation combined with results from a variety of measures of intellectual development and scientific reasoning, we are starting to understand the mosaic of the child's behavior in the free choice situation.

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FIGURE 1

Challenge Format for Activities

SNAIL WALK

Challenge: Try to get a snail to walk across a plastic circle placed on a table. Start the snail 3 feet away from the circle. See if the snail will cross the circle 3 out of 5 trials. Complete the experiment in one hour.

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Materials

2 lights
2 reflectors

Solution

1. Set up a light source and reflector and turn it on. Place 2 or 3 snails in front of it.

Which way do the snails move? (Describe or draw a picture.)

What variables are affecting the snails in this experiment?

2. Hold a turned on light source behind a snail and keep moving it towards the snail as the snail moves.

What happens?

What variables do you think the snail is responding to in this experiment?

Using the light source in this way, see if you can solve the problem of getting the snail to walk across the circle.

Describe your solution.

Try to find another way to solve the problem.

INCLINED PLANE

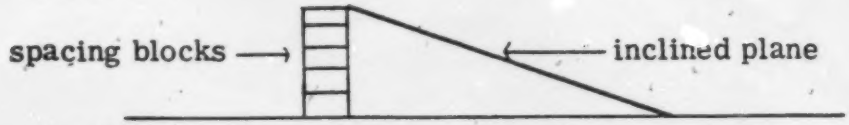
CHALLENGE: Get a block of wood to slide down an inclined plane that is 10 centimeters high at one end.

Materials

1 rubber coated sliding board	salt
15 spacing blocks	sand
1 formica coated block	flour

Solution

1. Set up the inclined plane with 5 spacing blocks. (Each block is 2 centimeters.)



2. Try sliding the block down the board, sprinkle flour on the board.

3. One variable is the height of the inclined plane. Another is the surface that the board slides on. Try using sand, salt, and flour on the plane. Try other variables that you think of.

NEW CHALLENGE: Do an experiment to show whether a heavy or light block slides down an incline more easily.

FIGURE 2

Challenge and Follow Up Format for Activities

BOILED EGGS

ACTIVITY: Find three ways to tell if an egg is raw or hard boiled without breaking the shell.

MATERIALS (MB)-in Master Box

2 eggs: 1 hard boiled, 1 raw
container (MB)
salt (MB)
teaspoon (MB)
heat/light source (MB)

DIRECTIONS

1. You have two eggs. One of the eggs is raw. The other is hard boiled. Mark one of the eggs with your pencil so you can tell them apart. Now think of ways these eggs might differ. [These are variables.] For example they might differ in size or color.

2. Try these experiments. Add any experiments that you think of.

	Result for Unmarked Egg	Result for Marked Egg
1. Tap the eggs. How do they sound?		
2. Hold the eggs up to the light. Can you see through them?		
3. Spin the eggs, count the number of spins.		
4. Make a salt water solution, with 1 spoon of salt for each cup of water. Do the eggs sink or float?		
5. Your experiment: (describe)		

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3. Boiled eggs spin more than unboiled eggs.

Which of your eggs was boiled? Unmarked _____ Marked _____

If you can't see through an egg, do you think you could spin it so it would go around five times? Yes _____ No _____ Explain _____

_____

_____

BOILED EGGS
CHALLENGE #1: Find a way to tell an egg boiled for three minutes from an egg boiled for six minutes.

BOILED EGGS
CHALLENGE #2: Find another way to tell if an egg is raw or boiled without cracking it.

DON'T TIP THE RAFT

ACTIVITY: See how many washers you can place on the yellow and the blue raft without causing them to tip over or sink.

MATERIALS (MB) - in Master Box

Yellow raft
Blue raft
Red raft
Green mystery raft (For Challenge)

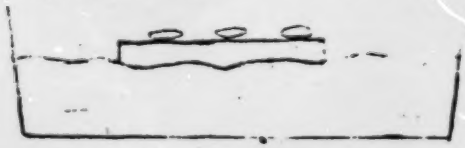
Bowl (MB)
Water supply
Paper towels (MB)
Container of #5 washers (MB)

DIRECTIONS

1. Add water to your bowl.

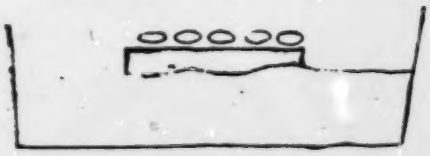
3/4' full

2. Put your yellow raft in the water. Add washers until it tips or sinks.



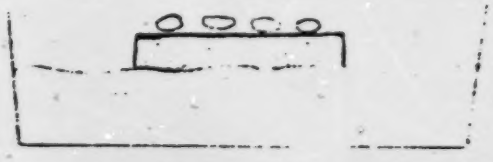
How many does it hold?
_____ washers.

3. Do the same with the blue raft.



How many does it hold?
_____ washers.

4. Look at the red raft. How many washers do you predict it will hold? _____ washers.



Try it. How many does it hold?
_____ washers.

The thickness of the rafts changes in these activities. It is a variable. What does making the raft thicker do to the number of washers it can hold?

_____

_____

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What things are the same about these rafts?

_____

_____

DON'T TIP THE RAFT
CHALLENGE #1: Predict how many washers you think the green mystery raft will hold. _____ washers

How did you decide? _____

_____

Do the experiment. Results: It held _____ washers.

DON'T TIP THE RAFT
CHALLENGE #2: Get the blue raft to float with 6 more washers on it than the green raft held.

How did you do it?

DON'T TIP THE RAFT
CHALLENGE #3: Get the blue raft to sink or tip with 6 fewer washers on it than the green raft held.

How did you do it?

FIGURE 3

Student Report and Interview Form

Student Report Form

Name _____ Date _____

Title of Experiment:

Description of Experiment: (What you are going to do.)

Variables:

What you changed. How you changed it.

Results:

Interview

What project did you choose?

About how long (how many hours) did you spend on this project?

What did you like the least about this project? Why?

When did you need help from the leader? Why?

What other challenges for these materials did you try?

What did you find out about that wasn't asked for in the instructions?

Now, tell me in your own words what you did while you were working on this project, and how you felt about it. (The answer will be TAPED. In taping, first give your name, the date, and the activity used before answering the questions.)

FIGURE 4

Examples of Questions on Ability to Control Variables

1. Suppose you want to find out whether the red sphere or the tan sphere might make the target move farther. To find out you could release each sphere and let it hit the target as shown below.

At which position would you start the red sphere? (Circle your choice)

High Middle Low

At which position would you start the tan sphere? (Circle your choice)

High Middle Low

Please explain how you chose your answer. _____

_____

2. Suppose Bill wants to prove that the high position is better than the low position to make the target go far. He does these experiments:

Trial 1

Trial 2

Barbara says he can't find out by doing these experiments. Why do you think she said that? _____

How could you improve the experiments? _____

_____